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Conversational AI Revolution: A Comparative Review of Machine Learning Algorithms in Chatbot Evolution

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Abstract

Chatterbots, also known as chatbots, have become essential for improving human-computer interaction in a number of fields, including e-commerce, healthcare, education, and customer support. From rule-based systems like ELIZA to contemporary AI-driven solutions employing modern machine learning (ML) techniques, this review paper examines the development of chatbots. It highlights how ML technologies, such as decision trees (DT), support vector machines (SVM), linear regression, and natural language processing (NLP), can be used to build chatbots that are more context-aware, responsive, and adaptive. The paper highlights important advances including deep learning, multimodal capabilities, and continuous learning mechanisms by looking at recent advancements and the mathematical models that support these techniques. These developments have driven an increasing support for chatbots by allowing them to provide personalized interactions, enhance accessibility, and reduce repetitive tasks. In order to open the door for further study and applications, this paper aims to bring light on the challenges and the efficacy of using ML into chatbot building.

Keywords: Machine Learning, Chatbots, Decision Tree, Support Vector Machine, Linear Regression, Natural Language Processing, K-Nearest Neighbor.

1. Introduction

In recent years, Conversational Artificial Intelligence (AI) has emerged as a transformative technology, revolutionizing human-machine interaction. Chatbots, powered by machine learning (ML) and natural language processing (NLP), have evolved from simple rule-based systems to sophisticated AI-driven conversational agents capable of understanding and responding to complex user queries. With advancements in deep learning, reinforcement learning, and hybrid AI models, chatbots are now widely deployed across various industries, including customer service, healthcare, education, and e-commerce [1].

This paper provides a comparative review of machine learning algorithms used in chatbot development, analyzing their evolution, performance, and real-world applications. Traditional methods, such as decision trees and support vector machines (SVMs), laid the foundation for chatbot intelligence, while modern deep learning architectures, including recurrent neural networks (RNNs), transformers, and reinforcement learning models, have significantly enhanced conversational capabilities[2],[3].

The review explores key challenges in chatbot development, including context retention, sentiment analysis, personalization, and ethical considerations. Additionally, it highlights emerging trends, such as multi-modal AI chatbots, few-shot learning, and generative AI models like GPT, which are reshaping the future of conversational AI.

By presenting a comparative analysis of machine learning algorithms, this study aims to provide insights into the strengths, limitations, and optimal use cases of different chatbot architectures. The findings will

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assist researchers and industry professionals in selecting appropriate ML techniques for developing more intelligent, efficient, and human-like conversational agents.

1.1 Overview of Chatterbots

Chatbots are now a familiar feature of human-computer interaction in recent years they have become strategic tools in most organizations. These interactive entities are a new type of software that imitates human conversation using text or voice to offer various services, from support to learning. AI and NLP technologies are used to study user inputs to return suitable responses as an organization has the chance to provide timely services 24/7 with the help of chatbots while augmenting its characteristic processes and providing the best user experience possible [4].

Chatbots refer to computer programs that mimic a human-like figure with the ability to engage in interaction and respond according to scripts set or otherwise programmed. It can be integrated with web, mobile, and other applications like social media messaging services to accommodate different forms. Customer service interactions, personal assistants, healthcare, online shopping, and education industries apply chatbots most frequently and in various others. There is a general agreement that the primary reasons for the growing use of chatbots relate to the fact that they entertain a fast response rate, create as much individual communication as necessary, and contribute to diminishing human burdens.

The rule-based expert chatbots work through the instructions that are coded into the system and are mostly inflexible and capable of handling simple tasks and dispelling simple answers. However, NLP and ML provide more flexible and dynamic responses as compared to a fixed script, all of these developments in NLP and ML have enabled the correspondingly advanced AI chatbots to be more versatile in their operation [5].

1.2 History of Chatbots

The history of chatbots started in the 1960s when Joseph Weizenbaum created the first chatbot called ELIZA at the Massachusetts Institute of Technology. Originally, it was based on simple pattern matching to imitate conversations, although copying a Rogerian psychotherapist. By today's standards ELIZA was primitive, nevertheless, this program proved that machines can indeed have simple conversations with people [6] [7].

PARRY was created in the 1970's by the Psychiatrist Kenneth Colby. While ELIZA was programmed simply to reflect an absence of personality, PARRY was designed to model a patient with schizophrenia elaborated with a detailed personality as well as language interpretation mechanism [7]. The first-generation chatbots set a precedent for conversational agents and machines that can engage us in natural language [7]. In the 1990s Richard Wallace created ALICE as an AI program that used the AI Markup Language (AIML) to improve it are responses [8] [9]. When compared to other models, ALICE was considered an improvement in chatbot design which even proved capable of winning several AI competitions [9]. Later in 2001, Smarter Child was able to run on more common messaging services such as AIM and MSN Messenger as a form of entertainment that included interactive talk [10].

New technologies such as ML and deep learning braced the release of virtual assistants such as Siri by Apple Inc. (2011), Google Assistant by Google (2016), and Alexa by Amazon (2014) [10]. These systems are built on top of AI, NLP, and voice recognition to garner contextually intelligent responses, which created a revolution in digital assistants' solutions [10]. This evolution has prepared the way for the conversational models which have been pre-trained on huge datasets, including language text, and supplemented that with reinforcement learning for great and adaptive responsiveness.

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1.3 Motivation for Researching Chatbots

Chatbots have received a great interest in research and business contexts. The desire to look into chatbots comes from their possibility to revolutionize user experience and decrease the amount of manual work. By researching chatbots, we aim to achieve the following objectives:

a. Improve Customer Service: Customer service remains one of the main domains of chatbot applications. It frees up time because instead of making the user wait for a reply the chatbots can respond to their queries immediately. Studies on the practical usefulness and performance of these systems, in terms of user engagement, can improve these systems.
b. Automate Routine Processes: A lot of industries struggle with dealing with recurrent chores and calls. Chatbots can be used to deal with simple inquiries which means that customer care officers should deal with more complex problems. Analyzing chatbots allows for understanding the best practices for integrating them and thus their ability to perform these functions.
c. Enhance Accessibility and Reach: It is important to have a vehicle that isn't limited in its accessibility to the average user by things like high costs or even language barriers as those offered by chatbots. Focused on the discussion of the eccentricity of a certain type of chatbot, the article will help to enhance the effectiveness of their application for people with different disabilities.
d. Advanced AI and NLP Capabilities: Chatbots are a good example of applying AI and NLP and, at the same time, they offer a perfect chance to develop these fields. By analyzing the patterns of the conversation between users and the chatbot and getting feedback from the user, the developers of the chatbots can enhance the performance of the AI used and how they respond to unfamiliar scenarios.

1.4 Novelty of Modern Chatbots

Current chatbots demonstrate remarkable improvements as compared to the earlier versions, thanks to improvements in deep learning, NLP, and AI-grounded response generation. Today's chatbots do not rely on simple rules hence contrary to traditional chatbots, the new versions involve the use of superior AI technologies such as that enables them to recognize context and even initiate real-life flows of conversation and also learn from people's interactions with them. Key advancements in modern chatbots include:

a. Deep Learning and NLP: Chatbots present in the current generation use advanced deep learning models like transformers which help analyze huge amounts of data, learn from context, and produce sensible output [10].
b. Reinforcement Learning and Human Feedback: Modern chatbots apply reinforcement learning from people's feedback to adapt the dialogues they provide [10]. This training approach allows chatbots to supply likely and contextually proper responses that are also likely to meet the user's taste and needs.
c. Multimodal Capabilities: Some relativistic chatbot research of the current period has been done on multimodal chatbots that may recognize and analyze inputs in text, images, and audio. This versatility enables them to offer more complex user interactions than their fixed-form counterparts which provides a more realistic feel.
d. Personalization and Context Awareness: AIs in chatbots apply an experience and recall to provide customized responses to users based on their earlier conversations. This feature improves the interaction with the users as chatbots can proceed with the recommendations and answers based on the user input history.
e. Continuous Learning: Unlike primitive, narrow-scope program-based bots, today's chatbots have abilities to gain knowledge continuously. In conversations with users, they learn how the users use language, what new terms are used, and the relevant changing needs of the users; they become more efficient in the long run.

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2. Machine Learning techniques that are used in chatterbots

This review paper explores at a number of studies that have examined various methods of ML employed in chatbots.

2.1 Chatbots and Decision Tree

Indriana Widya's, et al point of view: the increasing use of digital healthcare has led to the development of maternal and child health mobile health (mHealth) services, mostly through community-based programs like Posyandu in Indonesia. While health professionals are limited in responding promptly, patients require media for consultation and decision-making. This study aimed to gather data from midwives and expectant mothers to create a DT model that would serve as the foundation for a semi-automated chatbot. Pregnant women (n = 10) and midwives (n = 12) participated in semi-structured focus group discussions (FGD) in March 2022 using an exploratory qualitative methodology. Three main topics emerged from the results, which included 38 codes, 15 categories, and 7 subthemes: health monitoring, information on maternal health services, and maternal health education. To ensure quality, the DT technique was applied to these themes based on user needs, evidence, and expert sources. In conclusion, maternal health and monitoring education can benefit from the use of a semi-automated chatbot, where serious situations should be communicated with midwives in a non-automated manner. Using the DT method helped with early identification, supported a clinical choice, and guaranteed high-quality content. Additionally, user evaluation must be measured in future studies [11].

According to Dillon Chrime, COVID-19 has affected healthcare systems and billions of people worldwide. However, as of right now, there isn't an open-source chatbot that can help patients and important healthcare stakeholders assess the possible severity of a COVID-19 infection or recognize other illnesses and bodily reactions that could increase the risk of developing severe cases of the virus. This initial study investigates the deficiency of a DT with binary classification of cases and non-cases based on age, bodily system, viral infection, comorbidities, and any symptoms in the development of the COVID-19 "case by case" chatbot. A DT that explained the tools required for stratification for the chatbot application and for interacting with the user using a set of relevant nodes was created after the literature review. 212 nodes were constructed from the total number of lucid nodes, which were then categorized by body systems, medical conditions, comorbidities, and relevant manifestations seen in the literature, ranging from heart diseases to lung disorders. This produced 63560 "what if" choices, explained why severe COVID-19 cases can be difficult to comprehend in some situations, and provided a way to understand the data required to validate the DT. The DT illustrates how process strengthening is achieved by classifying the viral infection by bodily system and by include comorbidities and symptoms in the framework. This prototype application offers insight into the kind of data needed for decision support help, even though the practical clinical DT is not suitable for COVID-19 cases [12].

Ibrahim Alnedhami's, et al point of view: As technology advances in the modern era, AI has become increasingly popular across all relevant domains. Indeed, automated chat systems, sometimes known as "smart conversation" chatbots, are one of these crucial areas. In this work, we present a smartphone app that allows pregnant women to chat automatically. To provide a healthcare assistant, they have utilized this technology. Every mother wants to bring a child into the world, thus the suggested health care system assists expectant mothers by talking with them about certain symptoms, identifying illnesses, and forecasting the delivery method. It serves a variety of purposes for expectant mothers, including advising them on safe medicine, healthful activity, and nutrition. The suggested chatbot system was developed using the ML approach, namely the DT model, rather than relying solely on rules. With the aid of ML techniques, user inputs that were not previously entered during training can be processed and answered with a high degree of accuracy. In addition, the system supports words with diacritical marks, fixes the majority of spelling and grammar mistakes, and has many other capabilities. The smart adviser was evaluated using a variety

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of conversational formulations after it had been trained multiple times. The accuracy of the evaluation was 85.45% [13].

According to Pavel Smutny et al.: In particular, the usage of chatbots as a way to communicate with the target audience has grown in popularity over the last ten years due to the widespread adoption of mobile devices. As a result, the use of these tools is expanding at a tremendous rate. In many contexts, these portable devices transform communication and promote learning in a variety of ways. This study concentrated on the usage of Facebook Messenger teaching chatbots to increase comprehension. The independent internet directory was examined in order to evaluate chatbots for this study, and 89 distinct chatbots were found. The author categorized each of the chatbots found in the study according to the type of development platform, language feature, and discussion topic. Lastly, 47 instructional chatbots on Facebook Messenger were assessed using the analytical hierarchy method in terms of teaching, impact, accessibility, and humanity. Our study demonstrated that using Facebook Messenger chatbots for education is as easy as suggesting educational topics and sending tailored messages. According to the findings, chatbots that are now being developed as part of instant messaging apps are still in their infancy as a teaching tool for AI. The outcome gives teachers a lesson to help them understand how to use chatbots in the classroom and a variety of chatbots to test out as recommended [14].

2.2 Chatbots and Support Vector Machine

Viewpoint of Show-Jane Yen et al. The issue of choosing and organizing an increasing volume of text data, to which access is frequently essential for information technology and Internet services, is a surprisingly pertinent problem. Over the past ten years, ML solutions—such as AI and pattern recognition—have proven to be highly effective and adaptable in a variety of industries. The technique of looking through large document collections for precise answer sentences is known as question answering (QA). A question classifier, simple document/passage retrievers, and the proposed context-ranking models are all parts of the ML based question answering system that this paper claims to have. The context-ranking model is instructed to reorder the passages that the initial retrievers found based on the question classifier's answer type. Learners can use this method to achieve flexible instructional characteristics, including word forms, syntactic aspects, and semantic word aspects. The proposed context-ranking model takes into account whether or not the input passage is pertinent to the query type while annexing rich information. The successive labeling of tasks is the foundation for that. We use question categorization standards and TREC-QA tracks to assess the suggested methodology. According to the accuracy test, the question classifier's accuracy was 85.60% when no further semantic or syntactic taggers were introduced. This accuracy increased to 88.60% when the extended term approach methods suggested in this paper and a fixed related-word list were included. The QA model using the gold TREC-provided relevant document set achieves an MRR rank of 0.563 on the TREC-10 QA test. The mean reciprocal rank for retrieving simple documents and passages is 0.342 [15].

The perspective of Jianwei Gong and others: When discussing driver assistance systems, and autonomous vehicles specifically, the issue of road detection is quite important. This research focuses on feature extraction and classification for front-view road identification. More precisely, we suggest a quick method for road detection using SVM and live self-supervised learning. The use of online training into the suggested road identification algorithm improves the system's flexibility and lowers the frequency of incorrectly identifying roads and non-road classifications by updating the training data. The strategy shown here can also be seen as another paradigm for self-supervised online learning in the context of using a classification-based approach for intelligent vehicle road identification [16].

David Agustriawan's, et al point of view: Every industry has seen a sharp rise in technological progress, particularly the healthcare sector. During this time, hospital management began to advance through the use of technical instruments and systems. Patient data can be saved and prepared methodically to be utilized as an appointment queue line once the hospital has configured the system. A chatbot that uses NLP to boost

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the effectiveness of healthcare services could be used to improve it. An ideal classifier that learns the classification hyperplane in a space map with the maximum distance (margin) to the training samples is the SVM approach. The SVM will forecast the recommended specialist based on the users' comorbidities and symptoms [17].

Melanie Lourens's, et al point of view: Appropriate healthcare is essential to a healthy lifestyle. Nevertheless, making an appointment with a doctor for any health condition might be quite difficult. The objective is to create a ML based medical chatbot that can recognize the ailment and provide basic information about it before a patient contacts a doctor. Using a medical robot will improve access to medical information and reduce healthcare costs. The bots are computer models that use speech recognition to interact with humans. The chatbot stores the information in a database so that it can identify the language phrases, choose a query, and respond. Text similarity and ranking are computed using mutual information, TF-IDF, and N-gram. For the given query, more similar phrases will be located, and each verb in the input word will be given a score. A supplier, an expert piece of software, answers questions that are ambiguous or not present in the system [18].

2.3 Chatbots and linear regression

Arunee Ratikan's, et al point of view: These days, daily routines include consuming junk food, not having enough time for exercise, and other things that cause health problems for older adults. The majority of senior citizens frequently experience high blood pressure as they age. Numerous serious illnesses can result from this condition. Furthermore, there are not many doctors working in the hospital. To provide prompt care, the doctor typically takes a brief note about symptoms, which may not be sufficient for a diagnosis. As a result, we suggested a chatbot for daily health monitoring for senior citizens. To establish a personal health record (PHR), we must gather information from the elderly. We create conversational chatbots to communicate with senior citizens through the LINE app. The results of this study complement the doctor's work because the doctor is better able to diagnose illnesses and provide treatment recommendations after reading the daily PHR. Additionally, the linear regression technique was created to track the trend of older people's blood pressure. As a result, they can prevent or alleviate certain illnesses through chatbot alerts and health maintenance [19].

R Thamilselvan's, et al point of view: Higher education institutions are incorporating AI to improve their website support and user experience in light of the upcoming technology revolutions. A chatbot built on GPT-2 has been created to help stakeholders, instructors, and students navigate college websites with ease. This research study's goal is to assist college websites by responding to user inquiries and forecasting students' cut-off marks depending on their academic achievement. To answer questions on admissions, course information, academic resources, administrative processes, and campus life, this AI-powered chatbot uses ML and NLP techniques. The developed chatbot, which focuses on Q&A exchanges, uses deep learning techniques to provide thorough and contextually relevant responses. The chatbot, which is based on OpenAI's GPT-2 model, is adept at producing text that appears human and is used in a variety of settings, such as information retrieval and customer service. Specifically, it uses regression models including Linear Regression, DT Regression, SVM Regression, Random Forest Regression, and XGBoost Regression to estimate admission cut-off marks. These models take into account several variables, including academic performance, department preferences, board exam difficulty, prior cut-off lists, joining year, quotas, and employment market demands. The prediction accuracy of the suggested chatbot is evaluated using performance evaluation metrics such as Mean Squared Error (MSE), Root Mean Square Error (RMSE), and R-squared. The chatbot improves the entire user experience of educational websites by thoroughly analyzing past student data to provide users with full replies and precise predictions about future academic success [20].

According to Cecilie Bertinussen Nordheim et al., chatbots are anticipated to play a significant role in customer service. The degree to which users trust these chatbots also affects how often they are used.

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However, the level of trust that people have in chatbots is still unknown. We propose a questionnaire survey with 154 participants that examines factors for customer service chatbot trust in order to close this knowledge gap. There were two sections to the study: An interpretive review of the significance of the well-established antecedents of trust in interactive systems, as well as a preliminary examination of other relevant factors for chatbot trust. In order to achieve this, one of four customer support chatbots was used to convert the participants. In light of the study's findings, we propose a preliminary research model of confidence in service chatbots that takes into account the inclination for technology adoption, perceived risk and brand, and perceived chatbot attributes (expertise and reaction time) [21].

2.4 Chatbots and natural language processing (NLP)

According to Suman Rajest et al., the goal of this project is to create a chatbot that will employ NLP to help its users. Chatbots are AI tools that conduct user interviews, comprehend user inquiries, provide answers, and help users in whatever manner they can. The goal of this application is to create a chatbot for customer service that can interact with customers and offer assistance in a few specific situations. This chatbot will process messages containing basic user requests, automatically assign a tag from one of the pre-existing tags, and provide the appropriate response. If the bot determines that the questions being asked are extremely complicated, it will forward the conversation to a real human assistant. The Natural Language Tool Kit (NLTK) and PyTorch (a Python Deep Learning package) will be used to develop the ML model upon which the Chatbot will be based. The model being used here is the feed forward neural network. The input layer, hidden layers, and output layer are the three layers that make up this neural network. The total number of unique words in the data set is equally distributed between the input and hidden layers of the network. Conversely, the number of nodes in the output corresponds to the number of distinct tags into which the provided data set is divided. This kind of neural network is ideal for the basic development of chatbots because it can be trained or used with little computational resources. Our coffee shop design has the ability to order coffee, make jokes, recommend drinks, and more. Because of this chatbot's rather high degree of customisation, many alternatives can be implemented into various circumstances. One significant feature of this chatbot is that, although the neural network itself seldom needs to be changed, the dataset it is trained on may be readily modified to include new tags. Because of this, the model is quite reliable. Chatbots like this one are being used in a variety of businesses, including government agencies, automated food delivery services, and the medical sector. Additionally, this feature makes it very simple to alter the chatbot's training and testing [22].

Lalwani et al.'s perspective: Software applications offer a variety of user interfaces, such as menus, forms, graphical user interfaces (GUIs), command lines, and natural language. Although UI can be divided into web-based and GUI types, there may be situations in which a different type of UI is required. This is why we require an interactive interface that allows users to communicate with information retrieval systems like chatterbots. The chatbot is a type of bot that has been accessible on chat networks. This is the tendency that has been noticed: the user can invoke them through graphical user interfaces or widgets. They frequently offer a stateful service, meaning that the application stores the data from each session. On a college's website, it's frequently impossible to even determine where to seek for information. It becomes challenging to obtain information when one does not work at or attend a specific university or college. A college inquiry chatbot provides a solution to the problems; it is a standard and educational widget that is quick, easy, and educational. Enhancing college websites' homepages gives users useful information that improves their experience. These days, chatbots—intelligent systems—are created using AI and NLP techniques. This interface manages a number of tasks, including exam cell, admission, academics, user attendance, grade point average, placement cell, and many more [23].

The viewpoint of Mustafa Raza Rabbani et al. AI is currently being seen to improve the banking and finance sector. It has undergone significant development and is probably going to continue to be a popular advancement for some time to come. The current study examines the impact that technologies play in the

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banking and finance industry as well as whether the use of AI has altered how banks and other financial services providers operate. One of the most important aspects of the banking and financial sector is customer interaction. For customers of Islamic banking and finance, this study suggests a chatbot platform based on NLP and AI. The suggested chatbot is currently the first of its kind to assist Islamic banking and finance till clients receive interactive Islamic financial solutions that comply with shariah for their particular needs [24].

Mohammed Benhmed and associates' perspective: Chatbots, also known as conversational agents, are conversational software programs that can communicate with actual people using a natural language interface. One of the fundamental tasks in AI and NLP is dialogue management. The best talking chatbot has taken years to construct, according to AI leaders. Although chatbots are capable of a wide range of functions, their primary function is to comprehend spoken language and initiate a suitable response. In the past, chatbot architectures were created using handwritten code, pre-established templates and conventions, or basic statistical techniques. Around 2015, end-to-end neural networks took the role of these models due to their improved learning capabilities. The encoder-decoder recurrent model is currently the modeling approach of conversations that is used more commonly. The scientific field of neural machine translation is where this approach was applied, and it shows impressive performance. To improve the conversational capabilities of chatbots, numerous features and modifications have been implemented thus far [25].

According to Hussam Abdulla et al., viewers are moving toward a society that will welcome more interaction between humans and machines as a result of AI's development in numerous economic sectors. Because of this, there are subfields like NLP that are used in chatbots and other technologies. In this regard, the current study uses recent and critical secondary research to discuss the development of chatbots using NLP by embracing AI and machine linguistics. These technologies allow devices to analyze text and facilitate text planning, sentence planning, and text realization for NLP [26].

The perspective of Vitaliy Husak and associates: The work focuses on developing an information system that uses chatbots and NLP to provide a list of stylish clothing recommendations that satisfy users' needs or expectations. It offers both scholarly and real-world applications for chatbots as voice interfaces for NLP. The goal of this project is to create software that would enable chatbot functionality in the already-available teleGRAM messenger. When installing other chatbots, similar chatbots with comparable functionality were examined, along with their benefits and drawbacks. A portion of the system's server is constructed with Java and the Spring Framework to process incoming data. IntelliJ IDEA is a programming environment in the form of an Integrated programming Environment, or IDE for short. In addition to attaining a high level of user language recognition, which has encouraged interaction and communication, NLP was also incorporated into the system through the DialogFlow service. The Bot API is used to establish a connection with the Telegram messenger. Once more, Hibernate is used as the data ORM for processing our database, while Jsoup is used for our parsers or for extracting web content [27].

2.5 Chatbots And K-Nearest Neighbour

Viny Christanti's, et al point of view: Nowadays, everything is done online, including office work, teaching, and learning, particularly in the domain of school administration. An informant must be able to meet the academic and non-academic information demands of students' parents and other stakeholders during the activity. One way to get around these requirements is with chatbots, which offer features that let users ask questions about where and when. Thus, it can be concluded that chatbots can be a public tool, particularly for schools, which can use them as a source of school information outside of their operations. The Modified K-Nearest Neighbor (MKNN) approach was used to create this chatbot. The most recent iteration of the K-Nearest Neighbor approach is called MKNN, and in its application, it performs additional steps after calculating Euclidean Distance and weight voting. In order to determine the shortest distance to the data class that is being addressed by carrying the weight of information biggest or most, the chatbot will first determine the value of the shortest distance to the database. Once this is done, it will calculate the value

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weight or information from that distance. This is the premise of the weight voting method itself. This makes it easier for the deep chatbot to identify a database's category and deliver more precise and certain responses [29].

From the perspective of Mr. PVM Vijay et al. Chatbots are gradually taking the place of humans in jobs that were formerly exclusively performed by humans, such as customer service or teaching. From basic rule-based chatbots to the current advanced AI chatbot era, the role of chatbots has expanded. These days, chatbots can effortlessly carry on a conversation by customizing their previous interactions with customers. This project's objective is to create a conversational robot that can be integrated into OpenAI's GPT-Chat. This novel approach has the potential to refocus future chatbot research in a particular direction. Based on the findings of our study, we propose a number of research avenues during our examination [29].

According to Omar Khadeer Hussain et al., we are living in the age of intelligent machines. As demonstrated by AI, ML, and deep learning, they are now also learning, appearing, and occasionally sobbing like humans. A chatbot, which is a conversational software agent activated using NLP, is a good illustration of such a computer. An overview of existing chatbots and the methods used in them is given in this study. The evolution, distinctions, and comparable features of the existing chatbots are specifically covered. We examined the features and technical details of 11 top chatbot application platforms by analyzing their attributes. According to a report, about 75% of customers are dissatisfied with the customer service they receive, and it might be difficult to come up with informed, thorough, and time-consuming responses these days. Historically, chatbot development techniques have depended on manually generated templates and rules. It was not long until end-to-end neural networks effectively replaced traditional models, and deep learning was just around the corner. To put it another way, Deep Neural Networks are the most effective generative-based model for solving conversational response generation issues. The authors of this study provisionally reviewed over 70 publications on the subject of chatbots that were published in the last five years based on a review of the literature. Overall, based on the literature review, this study compared a few selected studies using the technique employed. Additionally, this study explained how existing chatbot models affect conversation quality since they ignore certain aspects when producing responses [30].

According to Mutiwokuziva et al., in order to accomplish this, we constructed a chatbot in this study to evaluate the feasibility of teaching computers to translate natural language writing in the form of free-text and text messages. Using firsthand experience, this paper attempts to comprehend the methods, skill, and power of NLP with recurrent neural networks (RNN). We began our experiment using Google Word2vec and a sequence-to-sequence LSTMs cell neural network in order to do this. As a result, our results show that the type of output quality prediction is dependent on the number of training sessions and the caliber of the language model that was used to train our model bot. In this instance, an RNN-based chatbot demonstrates both generative abilities and thinking [31].

From the perspective of Akhtar Rasool et al: A conversational agent, commonly known as a chatbot, is a computer program that mimics human communication abilities. The development of communication is one of the most important phases in the creation of any type of chatbot. Even though AI and NLP have advanced significantly, developing a solid chatbot model remains a significant issue. A conversational bot can accomplish a lot of things. Stated differently, they ought to provide pertinent responses and have a basic understanding of the user's objective. Through the use of a vocal interface, this software program enables users to communicate with one another just as frequently as they would with a human. Because of this, they are utilized in practically every setting for client communication, including social media. These days, two basic models are used when developing a chatbot. two kinds of models: generative and retrieval-based. Thus, the earlier methods that relied on statistical techniques or handwritten instructions and patterns have been superseded by the breakthroughs in new approaches to AI and deep learning, such as end-to-end trainable neural networks. The current study suggests a different kind of deep learning, namely the use of deep neural learning to build a chatbot. When processing input and using the network's output, this method uses a multi-layer neural network [32].

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According to Bhartiya et al., chatbots have proven to be successful in lowering people's workloads since they offer automated solutions that mimic human involvement in a variety of business and societal challenges. The design and implementation of a university counseling auto-reply bot to respond to inquiries regarding engineering at the university level are thoroughly described in this work. The problem of overfitting was resolved once we applied the appropriate NLP to the JSON-formatted data from our university, which had been trained using a feedforward neural network. The user will be able to view the message in the Facebook Messenger interface as a useful tool for communication the next time they log in after the chat application has been linked into Facebook Messenger. The probability scores of correct answers increased somewhat from 0.46 for the first end-user test phase to 0.72 for the second end-user test phase when additional training phrases and keywords were added to the dataset [33].

3. Mathematical models of ML algorithms

3.1 Decision Tree's Mathematical Model

A DT consists of decision points represented by nodes (N), where edges (E) indicate the outcomes of splits or tests performed at these nodes, and leaves (L) serve as terminal nodes that provide either a value for regression or a class label for classification. When building a tree, it is essential to split a dataset S at each node. The working principle of DT algorithm as shown in Figure 1. Typical standards consist of:

a. Gini Impurity Classification

$$G(s) = 1 - \sum_{i=1}^{k} pi^2 \quad (1)$$

Where pi is the proportion of samples in S belonging to class i, and k is the number of classes [35].

b. Information Gain Classification

$$IG(S, A) = H(S) - \sum_{v \in \boldsymbol{values}(\boldsymbol{A})} \frac{|Sv|}{|S|} H(Sv) \quad (2)$$

Where:

$$H(s) = - \sum_{i=1}^{k} pi \; log_2 \; (pi) \quad (3)$$

is the entropy of the subset S, and Sv is the subset of samples for which feature A has value v [36].

c. Variance Reduction Regression

$$V R (S, A) = \mathrm{Var}(S) - \sum_{v \in \mathrm{values(A)}} \frac{|Sv|}{|S|} \mathrm{Var}(Sv) \quad (4)$$

Where:

$$\mathrm{Var}(S) = \frac{1}{|S|} - \sum_{i \in S} (yi - \bar{y})^2. \quad (5)$$

Here, yi is the target value, and $\bar{y}$ is the mean of y in S [34].

d. Conditions of Stopping

When one or more of the following circumstances are satisfied, the recursive splitting comes to an end, the maximum depth, d max, is attained. A node's minimum sample count ($n$min n min) is less than a threshold. Impurity and variance are not considerably reduced by additional splits [38]. Prediction for a new input x: from the root to a leaf on the tree. To follow the associated edge, assess the circumstances at each node. At the leaf, return the value:

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- Classification: The leaf's majority class label [39].
- Regression: The leaf's mean of the target values [39].

In terms of mathematics:

$$T(x) = \begin{cases} ci \; if \; x \in \text{Lead } i \text{ with class label } ci \\ \bar{y}i \; if \; x \in \text{Lead } i \text{ with mean target } \bar{y}i \end{cases} \quad (6)$$

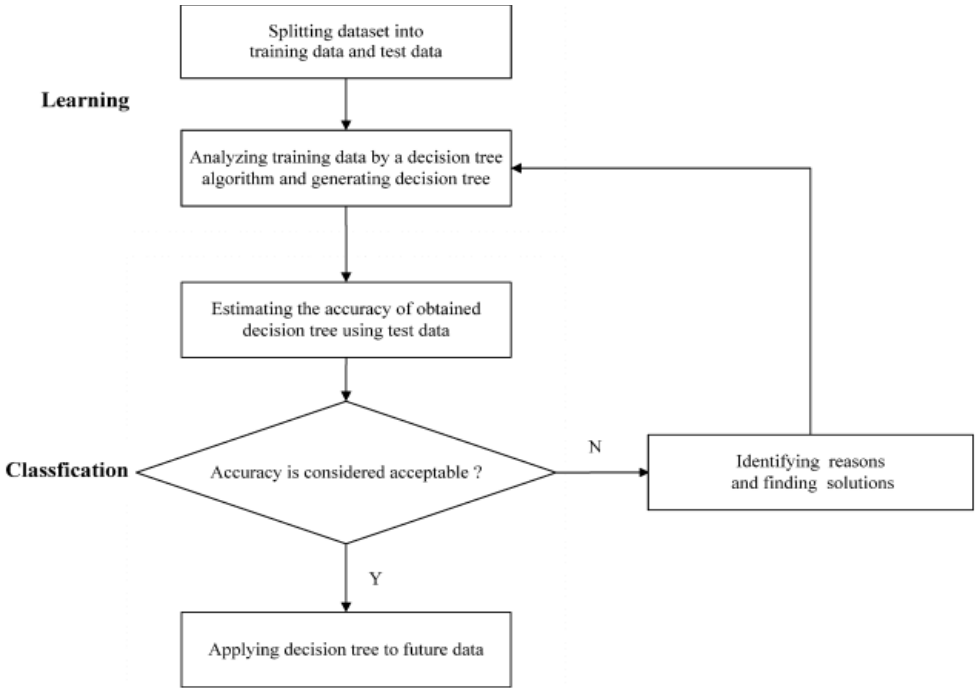

Figure 1: DT working principle flowchart [34].

3.2 Support vector machine's mathematical model

Finding the hyperplane that best divides the data points from several classes is the main concept. The working principle of SVM algorithm as shown in figure 2.

a. Linear classification

Given set of training data $\{(xi, yi)\}$ where $xi \in \mathbb{R}^{n}$ (input vectors) and $yi \in$ {-1, +1} (class labels), the SVM seeks a hyperplane $w.x + b = 0$ that maximizes the margin between the two classes. The objectives are to find the optimal values of w and b that satisfy the following constraints:

$$yi(w.xi + b) \geq 1, \forall i = 1, 2, \dots, N \quad (7)$$

Where:

$\boldsymbol{w}$ is the weight vector normal to the hyperplane.

$\boldsymbol{b}$ is the bias term, shifting the hyperplane.

$\boldsymbol{N}$ is the total number of training samples [41].

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b. Maximizing the Margin

The margin between the two classes is defined as the distance from the closest point to the hyperplane, and the goal is to maximize this margin. The margin is given by:

$$\text{Margin} = \frac{1}{||w||} \tag{8}$$

Thus, the objective becomes to maximize $\frac{1}{||w||}$, which is equivalent to minimizing $\frac{1}{2}||w||^2$. The optimization problem becomes:

$$\underset{(w,b)}{\boldsymbol{min}} \frac{1}{2}||\boldsymbol{w}||^2$$

subject to

$yi(w.xi + b) \geq 1,$
$\forall i = 1, 2, \ldots, N$ [41].

c. Kernel Trick (Nonlinear Classification)

For linearly non-separable data, SVM uses a kernel function $K(x, \acute{x})$ to map the input data into a higher-dimensional space where a linear separator can be found. The decision rule becomes:

$$f(x) = sign(\sum_{i=1}^{N} ai\ yi\ K\ (x, \acute{x}) + b) \tag{9}$$

Where:

$\boldsymbol{ai}$ are Lagrange multipliers determined by solving the optimization problem.

$\boldsymbol{K(x, \acute{x})}$is the kernel function, commonly the Radial Basis Function (RBF), polynomial kernel, etc [42].

d. Dual Problem

To solve the optimization problem, the Lagrangian dual form is often used. The dual formulation of the SVM optimization problem is:

$$\underset{a}{max}(\sum_{i=1}^{N} ai - \frac{1}{2} \sum_{ij=1}^{N} ai\ aj\ yi\ yj\ K(xi, xj)) \tag{10}$$

Subject to the constrains:

$$0 \leq ai \leq C, \sum_{i=1}^{N} ai\ yi = 0 \tag{11}$$

Where C is the regularization parameter that controls the trade-off between maximizing the margin and minimizing the classification error [43].

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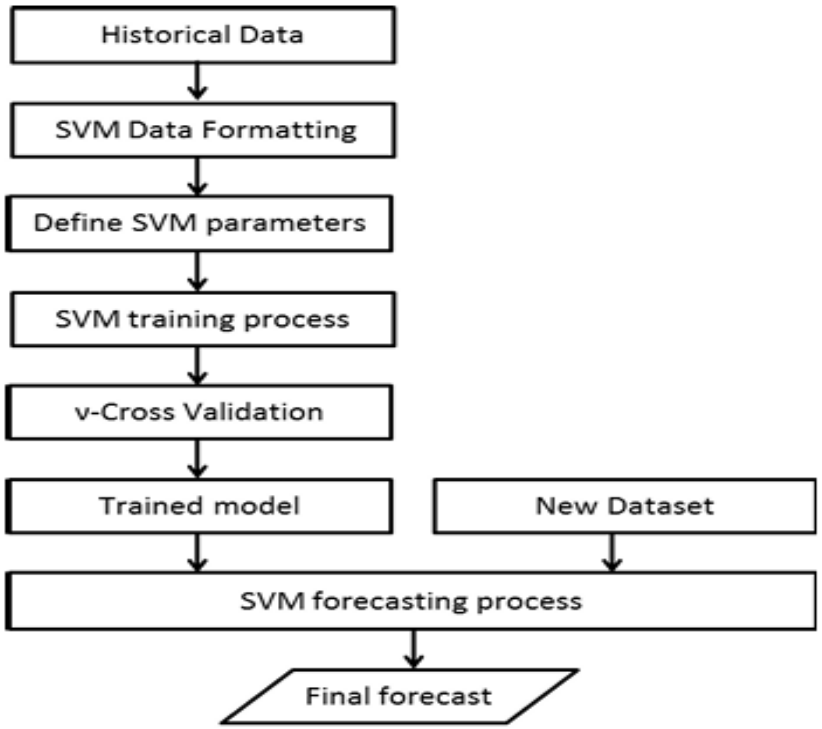

Figure 2: SVM working principle flowchart [40].

3.3 Natural language processing's mathematical model

A branch of AI called NLP studies how computers and human languages interact. Enabling machines to comprehend, interpret, and produce human language is the aim. Numerous mathematical models and methods that focus on language's structure, grammar, and semantics are used in this process [44]. Figure (3) shows a NLP algorithm used to build a healthcare chatbot model.

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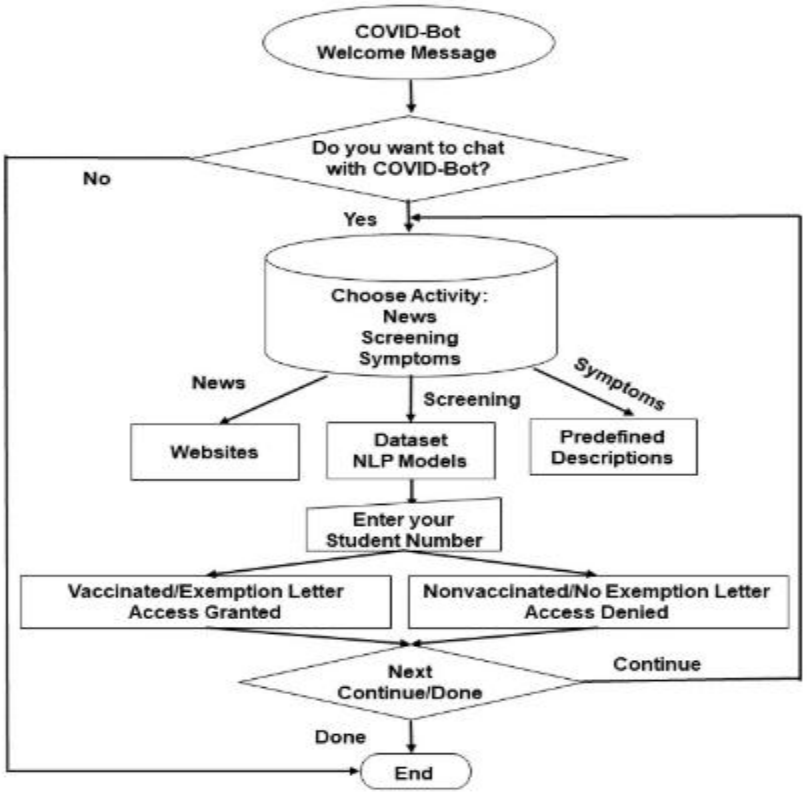

Figure 3: NLP chatbot model [45].

a. Tokenization

Tokenization is one of the first steps in NLP, where text is split into smaller units, such as words or sentences, called tokens. Mathematically, tokenization can be represented as a function $T: \mathcal{L} \rightarrow \mathcal{L}^*$, where $\mathcal{L}$ represents the input language (sequence of characters) and $\mathcal{L}^*$ represents the output sequence of token [46].

b. Part-of-Speech (POS) Tagging

In POS tagging, each token in a sentence is assigned agrammatical label, such as noun, verb, or adjective. The process can be mathematically expressed as a function $P: \mathcal{L}^* \rightarrow \mathbb{P}$, where $\mathcal{L}^*$ is the set of tokens and $\mathbb{P}$ is the set of part-of-speech labels. Probabilistic models, such as Hidden Markov Models (HMM), are commonly used to model this task [47].

c. Named Entity Recognition (NER)

NER involves identifying entities such as names, locations, and organizations from text. This can be framed as a sequence labeling problem. Mathematically, for a sequence of tokens $x1, x2, \dots \dots \dots , xn$, NER assigns each token a label from a set $L = \{Person, Location, Organization, \dots \dots \dots\}, such\ that$:

$$yi = f(xi), \qquad \forall i = 1, 2, \dots, n \tag{12}$$

Where yi represents the entity label assigned to each token xi [48].

d. Sentiment Analysis

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Sentiment analysis assigns a sentiment label (positive, negative, or neutral) to a given piece of text.

This can be represented as:

$$S = f(T) \tag{13}$$

Where S is the sentiment label and T is the tokenized input text. ML models like SVM or deep learning architectures such as RNN[49] are often used for sentiment classification [50].

e. Word Embeddings

Word embeddings are vector representations of words that capture semantic relationships between words. One common approach to word embeddings is through techniques. The embedding for a word w is represented as a dense vector $v_w \in \mathbb{R}^{\boldsymbol{d}}$, where d is the embedding dimension. The relationship between words can be captured by the cosine similarity between their vectors:

$$Cos(\theta) = \frac{v_w \cdot v_u}{||v_w|| \cdot ||v_u||} \tag{14}$$

Where v_w and v_u are the word vectors for words w and u, and θ is the angle between them [51].

f. Machine translator

Machine translator involves translating text from one language to another. In statistical machine translation (SMT), this process can be represented using a probability distribution:

$$P(t|s) = \frac{P(s|t)\,P(t)}{P(s)} \tag{15}$$

Where $P(t|s)$ is the probability of target sentence t given the source sentence s, $P(s|t)$ is the translation model, $P(t)$ is the language model for the target sentence, and $P(s)$ is the language model for the source sentence [48].

4. Conclusion

The integration of ML algorithms has significantly enhanced the capabilities of chatbots, transforming them from simple, rule-based systems into sophisticated tools capable of understanding and generating human-like responses. Advanced techniques, such as DT, SVM, linear regression, and NLP, enable chatbots to provide personalized, context-aware interactions across various domains, including healthcare, customer service, and education. Despite the remarkable progress, challenges remain in areas like accuracy, adaptability, and trustworthiness, emphasizing the need for ongoing research to further improve the functionality and reliability of these intelligent conversational agents.

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